

**A MULTI-CHASSIS BROADCAST ROUTER**  
**HAVING A COMMON CLOCK**

**CROSS REFERENCE**

This application is related to U.S. Provisional Patent Application Ser. No. 60/390,846 filed June 21, 2002.

This application is also related to co-pending U.S. Patent Application Ser. Nos. PCT/\_\_\_\_\_ (Atty. Docket No. IU010620), PCT/\_\_\_\_\_ (Atty. Docket No. IU020157),  
10 PCT/\_\_\_\_\_ (Atty. Docket No. IU020158), PCT/\_\_\_\_\_ (Atty. Docket No. IU020159),  
PCT/\_\_\_\_\_ (Atty. Docket No. IU020160), PCT/\_\_\_\_\_ (Atty. Docket No. IU020161),  
PCT/\_\_\_\_\_ (Atty. Docket No. IU020162), PCT/\_\_\_\_\_ (Atty. Docket No. IU020252),  
PCT/\_\_\_\_\_ (Atty. Docket No. IU020254), PCT/\_\_\_\_\_ (Atty. Docket No. IU020255)  
and PCT/\_\_\_\_\_ (Atty. Docket No. IU020256), all of which were assigned to the  
15 Assignee of the present application and hereby incorporated by reference as if reproduced in  
their entirety.

**FIELD OF THE INVENTION**

The present invention relates to broadcast routers and, more particularly, to a multi-chassis broadcast router having a common clock.

**BACKGROUND OF THE INVENTION**

20 A broadcast router allows each one of a plurality of outputs therefrom to be assigned the signal from any one of a plurality of inputs thereto. For example, an N x M broadcast router has N inputs and M outputs coupled together by a router matrix which allows any one of the N inputs to be applied to each one of the M outputs. Many such broadcast routers are  
25 comprised of a single chassis which houses plural printed circuit boards, commonly referred to as "cards", interconnected in a wide variety of configurations. Oftentimes, larger broadcast routers are constructed by interconnecting plural smaller broadcast routers. For example, in U.S. Patent Application Ser. No. 10/\_\_\_\_\_ (Atty. Docket No. IU020160) and previously  
30 incorporated by reference, a fully redundant, linearly expandable 1,280 X 1,280 broadcast router formed by interconnecting five 256 X 256 broadcast routers was disclosed. In order for the multi-chassis broadcast router disclosed in that application to function, however, the same clock must be available in each chassis.

## SUMMARY OF THE INVENTION

In one embodiment, the present invention is directed to a multi-chassis broadcast router which includes plural chassis, in each of which a routing engine and at least one clock-demanding component reside. Also residing in a first one of the plural chassis is a master clock which is coupled to the clock-demanding components residing in each chassis of the broadcast router. Preferably, an input side of each routing engine of the broadcast router are coupled to one another in a fully connected topology by plural links which are also employed to distribute a common clock signal from the master clock to all of the clock-demanding components.

In another embodiment, the present invention is directed to a multi-chassis broadcast router which includes first and second chassis. Each chassis supportably mounts a primary router matrix card, a redundant router matrix card, at least one clock-demanding input card and at least one clock-demanding output card. A first master clock resides on the primary router matrix card supportably mounted by the first chassis while a second master clock resides on the redundant router matrix card supportably mounted by the second chassis. Each master clock is coupled to each of the clock-demanding input and output cards supportably mounted by the first chassis as well as the clock-demanding input and output cards supportably mounted by the second chassis. The first master clock supplies the clock-demanding cards coupled thereto with a common clock signal while, in the absence of the common clock signal, the second master clock will supply the clock-demanding cards coupled thereto with a redundant common clock signal. Control logic coupled to both the first and second master clocks determines whether the first master clock should issue the common clock signal or whether the second master clock should issue the redundant common clock signal in the absence of the common clock signal.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a fully redundant, linear expandable broadcast router; FIG. 2 is an expanded block diagram of a first broadcast router component of the fully redundant, linearly expandable broadcast router of FIG. 1;

FIG. 3 is an expanded block diagram of a second broadcast router component of the fully redundant, linearly expandable broadcast router of FIG. 1;

FIG. 4 is a state diagram for a state machine of the first broadcast router component of FIG. 2; and

FIG. 5 is a state diagram for a state machine of the second broadcast router component of FIG. 4.

### DETAILED DESCRIPTION

Referring first to FIG. 1, a multi-chassis broadcast router 100 configured such that, in accordance with one aspect of the teachings of the present invention, each chassis thereof shares a common clock, will now be described in greater detail. As disclosed herein, the broadcast router 100 is a fully redundant, linearly expandable broadcast router. It should be clearly understood, however, that it is fully contemplated that other types of multi-chassis broadcast routers besides the specific type of multi-chassis broadcast router disclosed herein may also be configured to share a common clock. It should be further understood that the teachings of the present invention are equally applicable to broadcast routers configured to include plural broadcast router components housed within a common chassis.

As may now be seen, the multi-chassis, fully redundant, linearly expandable broadcast router 100 is comprised of plural broadcast router components, each housed within a respective chassis, coupled to one another to form the larger fully redundant linearly expandable broadcast router 100. Each broadcast router component is a discrete router device which includes a first (or "primary") router matrix card and a second (or "redundant") router matrix card. Thus, each broadcast router component has first and second routing engines, one residing on each of the primary and redundant router matrix cards. As will be more fully described below, each one of the first and second routing engines of a broadcast router component receives, at an input side thereof, the same N input digital audio data streams and places, at an output side thereof, the same M output digital audio data streams. As disclosed herein, each of the broadcast router components used to construct the multi-chassis, fully redundant, linearly expandable broadcast router are N x M sized broadcast routers. However, it is fully contemplated that the multi-chassis, fully redundant, linearly expandable broadcast router 100 could instead be constructed of broadcast router components of different sizes relative to one another.

As further disclosed herein, the multi-chassis, fully redundant, linearly expandable broadcast router 100 is formed by coupling together first, second, third and fourth broadcast router components 102, 104, 106 and 108, each of which is housed in a discrete chassis. Of course, the present disclosure of the multi-chassis, fully redundant, linearly expandable broadcast router 100 as being formed of four broadcast router components 102, 104, 106 and

108 is purely by way of example. Accordingly, it should be clearly understood that a multi-chassis, fully redundant, linearly expandable broadcast router constructed in accordance with the teachings of the present invention may be formed using various other numbers of broadcast router components. As may be seen in FIG. 1, the first, second, third and fourth  
5 broadcast router components 102, 104, 106 and 108 which, when fully connected in the manner disclosed herein, collectively form the multi-chassis, fully redundant, linearly expandable broadcast router 100, are housed in respective chassis. In the alternative, of course, the first, second, third and fourth broadcast router components 102, 104, 106 and 108 may instead be housed together in a common chassis. Further, while, as previously set forth,  
10 each one of the first, second, third and fourth broadcast router components 102, 104, 106 and 108 may have different sizes relative to one another or, in the alternative, may all have the same N x M size, one size that has proven suitable for the uses contemplated herein is 256 x 256. Finally, a suitable configuration for the multi-chassis fully redundant, linear expandable broadcast router 100 would be to couple five broadcast router components, each sized at 256 x  
15 256 and housed in a discrete chassis, thereby resulting in a 1,280 x 1,280 broadcast router.

The first broadcast router component 102 of the multi-chassis, fully redundant, linearly expandable broadcast router 100 includes a chassis 102c, within which a primary router matrix card 102a and a redundant router matrix card 102b used to replace the primary router matrix card 102a in the event of a failure thereof, are supportably mounted. Similarly, the second  
20 broadcast router component 104 of the multi-chassis, fully redundant, linearly expandable broadcast router 100 includes a chassis 104c, within which a primary router matrix card 104a and a redundant router matrix card 104b used to replace the primary router matrix card 104a in the event of a failure thereof, are supportably mounted; the third broadcast router component 106 of the multi-chassis, fully redundant, linearly expandable broadcast router 100 includes a  
25 chassis 106c, within which a primary router matrix card 106a and a redundant router matrix card 106b used to replace the primary router matrix card 106a in the event of a failure thereof, are supportably mounted; and the fourth broadcast router component 108 of the multi-chassis, fully redundant, linearly expandable broadcast router 100 includes a chassis 108c, within which a primary router matrix card 108a and a redundant router matrix card 108b used to  
30 replace the primary router matrix card 108a in the event of a failure thereof, are supportably mounted. Of course, the designation of each of the router matrix cards 102b, 104b, 106b and 108b as a redundant matrix card for use as a backup for the router matrix cards 102a, 104a,

106a and 108a, respectively, in the event of a failure thereof is purely arbitrary and it is fully contemplated that either one of a router matrix card pair residing within a broadcast router component may act as a backup for the other of the router matrix pair residing within that broadcast router component.

5           While each of the broadcast router components 102, 104, 106 and 108 include a primary and redundant router matrix cards, as will be more fully described below, the primary router matrix card for a broadcast router component may or may not be generally identical to the redundant router matrix card for that broadcast router component. More specifically, for the first broadcast router component 102, the primary router matrix card 102a is structured  
10 differently from the redundant router matrix card 102b. Similarly, for the second broadcast router component 104, the primary router matrix card 104a is structured differently from the redundant router matrix card 104b. For the third and fourth broadcast router components, however, the primary router matrix cards 106a and 108a are generally identical to the redundant router matrix cards 106b and 108b, respectively. It should be noted, however, that  
15 for each of the broadcast router components 102, 104, 106 and 108, however, the routing engine residing on the primary router matrix card is generally identical to the routing engine residing on the redundant router matrix card.

As may be further seen in FIG. 1, the primary router matrix card 102a of the first broadcast router component 102, the primary router matrix card 104a of the second broadcast  
20 router component 104, the primary router matrix card 106a of the third broadcast router component 106 and the primary router matrix card 108a of the fourth broadcast router component 108 are coupled together in a first arrangement of router matrix cards which conforms to a fully connected topology. Similarly, the redundant router matrix card 102b of the first broadcast router component 102, the redundant router matrix card 104b of the second  
25 broadcast router component 104, the redundant router matrix card 106b of the third broadcast router component 106 and the redundant router matrix card 108b of the fourth broadcast router component 108 are coupled together in a second arrangement which, like the first arrangement, conforms to a fully connected topology. In a fully connected topology, each router matrix card of an arrangement of router matrix cards is coupled, by a discrete link, to  
30 each and every other router matrix card forming part of the arrangement of router matrix cards.

Thus, for the first arrangement of router matrix cards, first, second and third bi-directional links 110, 112 and 114 couples the primary router matrix card 102a residing within the chassis 102c of the first broadcast router component 102 to the primary router matrix card 104a residing within the chassis 104c of the second broadcast router component 104, the primary router matrix card 106a residing within the chassis 106c of the third broadcast router component 106 and the primary router matrix card 108a residing within the chassis 108c of the fourth broadcast router component 108, respectively. Additionally, fourth and fifth bi-directional links 116 and 118 couple the primary router matrix card 104a residing within the chassis 104c of the second broadcast router component 104 to the primary router matrix card 106a residing within the chassis 106c of the third broadcast router component 106 and the primary router matrix card 108a residing within the chassis 108c of the fourth broadcast router component 108, respectively. Finally, a sixth bi-directional link 120 couples the primary router matrix card 106a residing within the chassis 106c of the third broadcast router component 106 to the primary router matrix card 108a residing within the chassis 108c of the fourth broadcast router component 108.

Similarly, for the second arrangement of router matrix cards, first, second and third bi-directional links 122, 124 and 126 couples the redundant router matrix card 102b residing within the chassis 102c of the first broadcast router component 102 to the redundant router matrix card 104b residing within the chassis 104c of the second broadcast router component 104, the redundant router matrix card 106b residing within the chassis 106c of the third broadcast router component 106 and the redundant router matrix card 108b residing within the chassis 108c of the fourth broadcast router component 108, respectively. Additionally, fourth and fifth bi-directional links 128 and 130 couple the redundant router matrix card 104b residing within the chassis 104c of the second broadcast router component 104 to the redundant router matrix card 106b residing within the chassis 106c of the third broadcast router component 106 and the redundant router matrix card 108b residing within the chassis 108c of the fourth broadcast router component 108, respectively. Finally, a sixth bi-directional link 132 couples the redundant router matrix card 106b residing within the chassis 106c of the third broadcast router component 106 to the redundant router matrix card 108b residing within the chassis 108c of the fourth broadcast router component 108.

The first, second, third and fourth broadcast router components 102, 104, 106 and 108 will now be described in greater detail. FIG. 2 shows the first broadcast router component

102. As previously set forth, the first broadcast router component 102 includes a primary router matrix card 102a and a redundant router matrix card 102b, each of which are slideably received within and supportably mounted by the chassis 102c (not shown in FIG. 2) of the first broadcast router component 102. Also slideably received within and supportably mounted by  
5 the chassis 102 are input cards 136-1 through 136-N and output cards 138-1 through 138-M. Each input card 136-1 through 136-N is coupled to the primary router matrix card 102a and the redundant router matrix card 102b. Likewise, each output card 138-1 through 138-M is coupled to the primary router matrix card 102a and the redundant router matrix card 102b. Of course, while discrete input and output cards 136-1 through 136-N and 138-1 through 138-M  
10 are shown in FIG. 2, it should be clearly understood that, if desired, the functionality residing on both the input and output cards card, for example, the input card 136-1 and the output card 138-1 may instead be placed on a single input/output ("I/O") card. Furthermore, while FIG. 2 shows discrete input and output cards 136-1 through 136-N and 138-1 through 138-M, it is fully contemplated that, depending on available space thereon, all or part of the functionality  
15 shown as residing on either the input cards, for example, the input card 136-1, the output cards, for example, the output card 138-1, or both, may instead reside on the primary router matrix card 102a, the redundant router matrix card 102b or some combination thereof.

Residing on each input card 136-1 through 136-N is input signal selection circuitry (not shown). The input signal selection circuitry selects, from plural input signals received  
20 thereby, an input signal to be passed to both the primary router matrix card 102a and the redundant router matrix card 102b. Typically, the input signal selection circuitry is used to select between an input digital audio data stream conforming to the Audio Engineering Society-11 ("AES-11") standard and an input digital audio data stream conforming to the multichannel digital audio interface ("MADI") standard set forth in the AES-10 standard. In  
25 this regard, it should be noted that a MADI input digital audio data stream may contain up to 32 AES digital audio data streams and that each of the inputs to the input selection circuitry would typically contain a single AES digital audio data stream which had previously been extracted from a MADI input digital audio data stream by extraction circuitry (also not shown). Of course, such a configuration is purely exemplary and it is fully contemplated that  
30 input signal selection circuitry is not necessary if the first broadcast router component 102 is instead configured to receive, as inputs thereto, a single type of digital audio data.

As the input selection circuitry residing on each one of the input cards 136-1 through 136-N selects an input digital audio stream to be transmitted to each one of the primary and redundant router matrix cards 102a and 102b, each one of the primary and redundant router matrix cards 102a and 102b receive, from the input cards 136-1 through 136-N, input digital audio signals 1 through N, respectively. Residing on the primary router matrix card 102a are a routing engine ("RE") 140, a transmission expansion port ("EXP") 146, first, second and third receiving expansion ports (not shown), a first master clock ("CLK-A") 134 and a first state machine ("SM") 148. The input digital audio streams 1 through N propagating from the input cards 136-1 through 136-N are transmitted to the routing engine 140 and the transmission expansion port 146. Operation of the routing engine 140 and the transmission expansion port 146 are described in greater detail in co-pending U.S. Patent Application Ser. No. 10/\_\_\_\_\_ (Atty. Docket No IU020160) and previously incorporated by reference. Briefly, however, the N input digital audio data streams received by the transmission expansion port 146 are forwarded to the primary router matrix card 104a of the second router matrix component 104, the primary router matrix card 106a of the third router matrix component 106 and the primary router matrix card 108a of the fourth router matrix component 108. The router matrix cards 104a, 106a and 108a are similarly provided with a transmission expansion port which transmit input digital audio data streams N+1 through 2N, 2N+1 through 3N and 3N+1 through 4N respectively received thereby to the routing engine 140.

Together with the input digital audio data streams N+1 through 2N, 2N+1 through 3N and 3N+1 through 4N received from the second, third and fourth broadcast router components 104, 106 and 108, respectively, the input digital audio streams 1 through N output by the input cards 136-1 through 136-N are provided as inputs to the routing engine 140. Signal selection functionality residing on the routing engine 140 allows each one of the M outputs therefrom to be connected to a selected one of the 4N inputs thereto. Selection of the particular one of the 4N inputs to which each one of the M outputs is connected is controlled by control circuitry (also not shown). From the routing engine 140, each one of the M output digital audio data streams is propagated to a corresponding one of the output cards 138-1 through 138-M. Residing on each one of the output cards 138-1 through 138-M is output signal selection circuitry (not shown) which selects, from a first output digital audio data stream received from the first router matrix card 102a and a second output digital audio data stream received from



the second router matrix card 102b, a digital audio data stream to be output the first broadcast router component 102.

As previously set forth, the first master clock 134 and the first state machine 148 also reside on the first router matrix card 102a of the first broadcast router component 102. As will be more fully described below, the first master clock 134 provides a first common clock signal for all clock-demanding components of the broadcast router 100. As disclosed herein, the input and output cards for each of the broadcast router components 102, 104, 106 and 108 are designated as clock-demanding components. However, the foregoing disclosure is purely exemplary and it is fully contemplated that other components, including those shown in the drawings and/or omitted therefrom for ease of illustration, may also be clock-demanding components. Accordingly, the first common clock signal generated by the first master clock 134 is tied to a clock input CLK-A of each one of the input cards 136-1 through 136-N and the output cards 138-1 through 138-M. The first common clock signal generated by the first master clock 134 is also passed to the second broadcast router component 104 via the link 110 where it is tied to a clock input CLK-A of each one of the input cards 142-1 through 142-N and the output cards 144-1 through 144-M. It is contemplated that the first common clock signal generated by the first master clock 134 may be distributed to other broadcast router components, for example, the broadcast router component 104, using a variety of techniques. Preferably, the first master clock forwards the first common clock signal CLK-A to the transmission expansion port 146 where it is be added to the data signal being transmitted over the link 110 to the receiving expansion ports residing on the primary router matrix card 104a. Upon arrival of the data signal at the primary router matrix card 104a, the first common clock signal CLK-A is extracted from the data signal for subsequent distribution to the clock-demanding components of the primary router matrix card 104a. Alternately, it is contemplated that the first common clock signal CLK-A may be transmitted over the link 110 using a discrete line, for example, a conductive wire or optical fiber, to exclusively carry the first common clock signal by adding a line to the existing line or lines which individually or collectively form the link 110, for example, by intertwining the line carrying the first common clock signal with the lines carrying the digital audio data signals 1 through N from the transmission expansion port 146 to the second broadcast router component 104. In a similar fashion, the output of the first master clock 134 is also passed to the third and fourth broadcast router components 106 and 108 via the links 112 and 114, respectively, for distribution of the

first common clock signal to all of the input and output cards thereof as well. Of course, while FIG. 2 shows only input and output cards as clock-demanding components, it is fully contemplated that other components of the first broadcast router component 102 illustrated in FIG. 2, as well as components of the first broadcast router component 102 omitted from FIG. 2 for ease of illustration may also be clock-demanding components having a CLK-A input to be coupled to the second master clock 134.

The first master clock 134 is controlled by the first state machine 148. As may be further seen in FIG. 2, the state machine 148 has a first input coupled to the routing engine 140, a second input coupled to the transmission expansion port 146, a third input coupled to a routing engine 150 residing on the redundant router matrix card 104b of the second broadcast router component 104, a fourth input coupled to a transmission expansion port 152 residing on the redundant router matrix card 104b of the second broadcast router component 104 and an output coupled to the first master clock 134. As disclosed herein, the third and fourth inputs to the state machine 148 which originate at the second router matrix card 104b of the second broadcast router component 104 are coupled to the state machine 148 via the links 110 and 122, respectively. It is fully contemplated, however, that the third and fourth inputs may instead be coupled to the state machine 148 via the other one of the links or, if desired, both inputs may be coupled to the state machine 148 by either the link 110 or the link 122. Furthermore, while precise details of the operation of the state machine 148 will be more fully described below, briefly, the first state machine 148 selectively activates/deactivates the first master clock 134 based upon the operating condition for the routing engine 140, the transmission expansion port 146, the routing engine 150 and the transmission expansion port 152 coupled to the first, second, third and fourth inputs thereto.

Of the four components of the primary router matrix card 102a illustrated in FIG. 2, the redundant router matrix card 102b includes only a transmission expansion port (not shown) coupled to receive digital audio data input signals 1 through N from the input cards 136-1 through 136-N and a routing engine (also not shown) coupled to receive digital audio data signals 1 through N from the input cards 136-1 through 136-N, digital audio data signals N+1 through 2N from the redundant router matrix card 104b via the link 122, digital audio signals 2N+1 through 3N from the redundant router matrix card 106b via the link 124 and digital audio signals 3N+1 through 4N from the redundant router matrix card 108b via the link 126. The routing engine further includes M outputs coupled to output cards 1 through M,

respectively. Signal selection functionality residing within the routing engine each one of the M outputs therefrom to be connected to a selected one of the 4N inputs thereto. The routing engine 140 residing on the primary router matrix card 102a and the routing engine residing on the redundant router matrix card 102b are identically controlled so that the M output digital audio data streams for the primary router matrix card 102a are the same as the M output digital audio data streams for the redundant router matrix card 102b.

FIG. 3 shows the second broadcast router component 104. As previously set forth, the second broadcast router component 104 includes a primary router matrix card 104a and a redundant router matrix card 104b, each of which are slideably received within and supportably mounted by the chassis 104c (not shown in FIG.3) of the second broadcast router component 104. Also slideably received within and supportably mounted by the chassis 104 are input cards 142-1 through 142-N and output cards 144-1 through 144-M. Each input card 142-1 through 142-N is coupled to the primary router matrix card 104a and the redundant router matrix card 104b. Likewise, each output card 144-1 through 144-M is coupled to the primary router matrix card 104a and the redundant router matrix card 104b. Of course, while discrete input and output cards 142-1 through 142-N and 144-1 through 144-M are shown in FIG. 3, it should be clearly understood that, if desired, the functionality residing on both the input and output cards card, for example, the input card 142-1 and the output card 144-1 may instead be placed on a single I/O card. Furthermore, while FIG. 3 shows discrete input and output cards 142-1 through 142-N and 144-1 through 144-M, it is fully contemplated that, depending on available space thereon, all or part of the functionality shown as residing on either the input cards, for example, the input card 142-1, the output cards, for example, the output card 144-1, or both, may instead reside on the primary router matrix card 104a, the redundant router matrix card 104b or some combination thereof.

Residing on each input card 142-1 through 142-N is input signal selection circuitry (not shown). The input signal selection circuitry selects, from plural input signals received thereby, an input signal to be passed to both the primary router matrix card 104a and the redundant router matrix card 104b. Typically, the input selection circuitry is used to select between an input digital audio data stream conforming to the AES-11 standard and an input digital audio data stream conforming to the MADI standard set forth in the AES-10 standard. Again, in this regard, it should be noted that a MADI input digital audio data stream may contain up to 32 AES digital audio data streams and that each of the inputs to the input

selection circuitry would typically contain a single AES digital audio data stream which had previously been extracted from a MADI input digital audio data stream by extraction circuitry (also not shown). Of course, such a configuration is purely exemplary and it is fully contemplated that plural ones of the  $N+1$  through  $2N$  input digital audio data streams may be received from a single one of the input cards 142-1 through 142-N.

As the input selection circuitry residing on each one of the input cards 142-1 through 142-N selects an input digital audio data stream to be transmitted to each one of the primary and redundant router matrix cards 104a and 104b, each one of the primary and redundant router matrix cards 104a and 104b receive, from the input cards 142-1 through 142-N, input digital audio signals  $N+1$  through  $2N$ , respectively. Residing on the redundant router matrix card 104b are the routing engine 150, the transmission expansion port 152, first, second and third receiving expansion ports (not shown), a second master clock ("CLK-B") 154 and a state machine 156. The input digital audio streams  $N+1$  through  $2N$  propagating from the input cards 142-1 through 142-N, respectively, are transmitted to the routing engine 150 and the transmission expansion port 152. As previously noted, operation of the routing engine 150 and the transmission expansion port 152 are described in greater detail in co-pending U.S. Patent Application Ser. No. 10/\_\_\_\_\_ (Atty. Docket No IU020160) and previously incorporated by reference. Briefly, however, the input digital audio data streams  $N+1$  through  $2N$  received by the transmission expansion port 152 are forwarded to the redundant router matrix card 102b of the first router matrix component 102, the redundant router matrix card 106b of the third router matrix component 106 and the redundant router matrix card 108b of the fourth router matrix component 108. The router matrix cards 102b, 106b and 108b are similarly provided with a transmission expansion port which transmit input digital audio data streams 1 through  $N$ ,  $2N+1$  through  $3N$  and  $3N+1$  through  $4N$  respectively received thereby to the routing engine 150.

Together with the input digital audio data streams 1 through  $N$ ,  $2N+1$  through  $3N$  and  $3N+1$  through  $4N$  received from the first, third and fourth broadcast router components 102, 106 and 108, respectively, the  $N+1$  through  $2N$  input digital audio streams propagating from the input cards 142-1 through 142-N are provided as inputs to the routing engine 150. Signal selection functionality residing on the routing engine 150 allows each one of the  $M$  outputs therefrom to be connected to a selected one of the  $4N$  inputs thereto. Selection of the particular one of the  $4N$  inputs to which each one of the  $M$  outputs is connected is controlled

by control circuitry (also not shown). From the routing engine 150, each one of the M output digital audio data streams is propagated to a corresponding one of the output cards 144-1 through 144-M. Residing on each one of the output cards 144-1 through 144-M is output signal selection circuitry (not shown) which selects, from a first output digital audio data stream received from the first router matrix card 104a and a second output digital audio data stream received from the second router matrix card 104b, a digital audio data stream to be output the second broadcast router component 104.

As previously set forth, the second master clock 154 and the state machine 156 also reside on the second router matrix card 104b of the second broadcast router component 104.

As will be more fully described below, the second master clock 154 provides a second, redundant, common clock signal for all clock-demanding components of the broadcast router 100. Accordingly, the output of the second master clock 154 is tied to a clock input CLK-B of each one of the input cards 142-1 through 142-N and the output cards 144-1 through 144-M. The output of the second master clock 154 is also passed to the first broadcast router component 102 via the link 122 where it is tied to a clock input CLK-B of each one of the input cards 136-1 through 136-N and the output cards 138-1 through 138-M. Preferably, the second master clock 154 forwards the second common clock signal CLK-B to the transmission expansion port 152 where it is added to the data signal being transmitted over the link 122 to the receiving expansion ports residing on the primary router matrix card 102a. Upon arrival of the data signal at the primary router matrix card 102a, the second common clock signal CLK-B is extracted from the data signal for subsequent distribution to the clock-demanding components of the primary router matrix card 102a. Alternately, it is contemplated that the second common clock signal CLK-B may be transmitted over the link 124 using a discrete line, for example, a conductive wire or optical fiber, to exclusively carry the second common clock signal by adding a line to the existing line or lines which individually or collectively form the link 124, for example, by intertwining the line carrying the first common clock signal with the lines carrying the digital audio data signals N+1 through 2N from the transmission expansion port 152 to the first broadcast router component 104. Similarly, the output of the second master clock 154 is also passed to the third and fourth broadcast router components 106 and 108 via the links 128 and 130, respectively, for distribution to all of the input and output cards thereof as well. Of course, while FIG. 3 shows only input and output cards as clock-demanding components, it is fully contemplated that

other components of the second broadcast router component 104 illustrated in FIG. 3, as well as components of the second broadcast router component 104 omitted from FIG. 3 for ease of illustration may also be clock-demanding components having a CLK-B input to be coupled to the second master clock 154. It should be kept in mind, however, that all clock-demanding components of the multi-chassis, fully redundant, linearly expandable broadcast router 100 should be configured to include both CLK-A and CLK-B inputs respectively coupled to the first master clock 134 and the second master clock 154, respectively.

The second master clock 154 is controlled by the state machine 156. As may be further seen in FIG. 3, the state machine 156 has a first input coupled to the routing engine 150, a second input coupled to the transmission expansion port 152, a third input coupled to the routing engine 140 residing on the primary router matrix card 102a of the first broadcast router component 104, a fourth input coupled to the transmission expansion port 146 residing on the primary router matrix card 102a of the first broadcast router component 102 and an output coupled to the second master clock 154. As disclosed herein, the third and fourth inputs to the state machine-156 which originate at the first-router matrix card 102a of the first broadcast router component 102 are coupled to the state machine 156 via the links 122 and 110, respectively. It is fully contemplated, however, that the third and fourth inputs may instead be coupled to the state machine 156 via the other one of the links or, if desired, both inputs may be coupled to the state machine 156 by either the link 110 or the link 122. Furthermore, while precise details of the operation of the state machine 156 will be more fully described below, briefly, the state machine 156 selectively activates/deactivates the second master clock 154 based upon the operating conditions for the routing engine 150, the transmission expansion port 152, the routing engine 140 and the transmission expansion port 146 coupled thereto.

Of the four components of the redundant router matrix card 104b illustrated in FIG. 3, the primary router matrix card 104a includes only a transmission expansion port (not shown) coupled to receive digital audio data input signals  $N+1$  through  $2N$  from the input cards 142-1 through 142- $N$  and a routing engine (also not shown) coupled to receive digital audio data signals  $N+1$  through  $2N$  from the input cards 142-1 through 142- $N$ , digital audio data signals 1 through  $N$  from the primary router matrix card 102a via the link 110, digital audio signals  $2N+1$  through  $3N$  from the primary router matrix card 106a via the link 116 and digital audio signals  $3N+1$  through  $4N$  from the primary router matrix card 108a via the link 118. The

routing engine further includes M outputs coupled to output cards 1 through M, respectively. Signal selection functionality residing within the routing engine each one of the M outputs therefrom to be connected to a selected one of the 4N inputs thereto. The routing engine 150 residing on the redundant router matrix card 104b and the primary engine residing on the first router matrix card 104a are identically controlled so that the M output digital audio data streams for the primary router matrix card 104a are the same as the M output digital audio data streams for the redundant router matrix card 104b.

The third and fourth broadcast router components 106 and 108 are generally identical to one another and somewhat similar to the first and second broadcast router components 102 and 104. As previously set forth, the third broadcast router component 106 includes a primary router matrix card 106a and a redundant router matrix card 106b, each of which are slideably received within and supportably mounted by the chassis 106c. Similarly, the fourth broadcast router component 108 includes a primary router matrix card 108a and a redundant router matrix card 108b, each of which are slideably received within and supportably mounted by the chassis 108c. The primary and redundant router matrix cards 106a and 106b of the third broadcast router component 106, as well as the primary and redundant router matrix cards 108a and 108b of the fourth broadcast router component 108 are similarly generally identically configured to the redundant router matrix card 102b of the first broadcast router component 102 and/or the primary router matrix card 104a of the second broadcast router component 104. In other words, the primary router matrix cards 106a and 108a, as well as the redundant router matrix cards 106b and 108b all include a transmission expansion port, a routing engine and plural receiving expansion ports but include neither a master clock nor a state machine.

Each of the third and fourth broadcast router components 106 and 108 further include N input cards and M output cards, all of which are slideably received within and supportably mounted by the chassis 106c and 108c, respectively. Each input and output card of the third broadcast router component 106 is coupled to each one of the primary router matrix card 106a and the redundant router matrix card 106b. Similarly, each input and output card of the fourth broadcast router component 108 is coupled to each one of the primary router matrix card 108a and the redundant router matrix card 108b. Like the input and output cards of the first and second broadcast router components 102 and 104, each input and output card of the third and fourth broadcast router components 106 and 108 include both a CLK-A input and a CLK-B input tied to the first and second master clocks 134 and 154, respectively. More specifically,

the input and output cards of the third broadcast router component 106 are tied to the first master clock 134 via the link 112 and to the second master clock 154 via the link 128 while the input and output cards of the fourth broadcast router component 108 are tied to the first master clock 134 via the link 114 and to the second master clock 154 via the link 130.

5 As previously set forth, the clock-demanding components residing in each chassis 102c, 104c, 106c and 108c of the multi-chassis broadcast router 100 are coupled to receive a common clock signal, for example, the CLK-A signal generated by the first master clock 134. The clock-demanding components residing in each chassis 102c, 104c, 106c and 108c of the broadcast router 100 are further coupled to receive a redundant common clock signal, for  
 10 example, the CLK-B signal generated by the second master clock 154. Redundancy is handled in such a way, however, that any router matrix card, for example, the router matrix card 102a, or any chassis, for example, the chassis 104b can fail without causing the entire broadcast router 100 to fail. Table I, below, illustrates the logic implemented to enable this result. As used in Table I, below, a router matrix card for a broadcast router component is  
 15 deemed to be "OK" when the router matrix card is both present and running. Further, a transmission expansion port is deemed to be "locked" when the frequency of the clock signal received from the master clock which resides, with the transmission expansion port, on a router matrix card, is relatively constant.

| Primary Router Matrix Card 102a OK | TX Port 146 Locked | Redundant Router Matrix Card 104b OK | TX Port 152 Locked | Master Clock | Router Status |
|------------------------------------|--------------------|--------------------------------------|--------------------|--------------|---------------|
| Yes                                | Yes                | Don't Care                           | Don't Care         | Clock 134    | Full          |
| Yes                                | No                 | Yes                                  | Yes                | Clock 154    | Full          |
| No                                 | Don't Care         | Yes                                  | Yes                | Clock 154    | Full          |
| Yes                                | No                 | Yes                                  | No                 | Clock 134    | Partial       |
| No                                 | Don't Care         | Yes                                  | No                 | Clock 154    | Partial       |
| No                                 | Don't Care         | No                                   | Don't Care         | None         | None          |

Table I

20 As previously set forth, by implementing redundancy of the common clock signal in accordance with the requirements set forth in Table I, any router matrix card, for example, the router matrix card 102a or any chassis, for example, the chassis 104c, can fail without causing the entire broadcast router 100 to fail. More specifically, if the first broadcast router 102 is working properly, i.e., the router matrix card 102a is okay and the transmission expansion port  
 25 146 is locked, the first master clock 134 distributes clock signal CLK-A as a common clock signal to all of the clock-demanding components of the multi-chassis broadcast router 100,



thereby enabling the multi-chassis broadcast router 100 to operate at full status. If, however, the primary router matrix card 102a fails due to the transmission expansion port 146 becoming unlocked, while the first master clock can still generate the clock signal CLK-A, the clock signal can no longer be distributed throughout the multi-chassis broadcast router 100. In this situation, if the redundant router matrix card 104b is okay and the transmission expansion port 152 is locked, the second master clock 154 can distribute the clock signal CLK-B as a common clock signal to all of the clock-demanding components of the multi-chassis router 100, thereby enabling the multi-chassis broadcast router 100 to continue operating at full status. Similarly, if the primary router matrix card 102 has failed, for example, if the primary router matrix card 102a is missing, the first master clock 134 will be unable to supply the clock signal clock-A. Under this scenario, regardless of whether the transmission expansion port 146 is locked, the second master clock 154 shall, if the redundant router matrix card 104b is okay and the transmission expansion port 152 is locked, again distribute the clock signal CLK-B as a common clock signal to all of the clock-demanding components of the multi-chassis router 100, thereby enabling the multi-chassis broadcast router 100 to continue operating at full status.

If the primary router matrix card 102a is okay but neither transmission expansion port 146 nor transmission expansion port 152 are locked, the first master clock 134 shall be the master clock for the multi-chassis broadcast router 100. While the first master clock 134 is still able to generate the clock signal CLK-A, the clock signal CLK-A cannot be distributed to the other chassis of the multi-chassis broadcast router 100. As only the clock-demanding components of the broadcast router component 102 will have a common clock signal, the multi-chassis broadcast router 100 will be operating at partial status. If, on the other hand, the primary router matrix card 102a has failed, the redundant router matrix card 104b remains okay, but the transmission expansion port 152 is not locked, the second master clock 154 shall be the master clock for the multi-chassis broadcast router 100. While the second master clock 154 is still able to generate the clock signal CLK-B, the clock signal CLK-B cannot be distributed to the other chassis of the multi-chassis broadcast router 100. As only the clock-demanding components of the broadcast router component 104 will have a common clock signal, the multi-chassis broadcast router 100 will again be operating at partial status. Finally, if both the primary router matrix card 102a and the redundant router matrix card 104b have failed, there will be no master clock for the multi-chassis broadcast router and, as there will

not be a common clock signal available for the clock-demanding components of the multi-chassis broadcast router 100, the multi-broadcast router 100 will completely fail.

Table I, above, may be implemented using Boolean logic. However, by doing so, less than ideal behavior may occur. It is highly desirable to have the removal or insertion of primary or redundant router matrix cards not to cause any flaws in the outputs of the router. Use of a non-glitching clock mux circuits for switches between locked and not locked states and for switching between clocks will eliminate most problems. The problem is caused when master clocks 134 and 154 have slightly different frequencies. When a router matrix card is removed or fails, this result is unavoidable. However, insertion of a router matrix card does not necessarily have to result in this problem. In other words, it is advantageous if a newly inserted router matrix card does not become the master until needed.

An exemplary logical implementation of Table I, above is shown in the state diagrams illustrated in FIGS. 4 and 5. More specifically, the first state machine 148 has three states, a first ("master" (or "M")) state 158 in which the first state machine 148 issues an instruction to the first master clock 134 to issue the signal CLK-A to all of the clock-demanding components of the multi-chassis broadcast router 100, a second ("backup" (or "B")) state 160 where the first state machine 148 issues an instruction to the first master clock 134 not to issue the signal CLK-A to all of the clock-demanding components of the multi-chassis broadcast router 100 and a third ("dead" (or "D")) state 162 where the first state machine 148 will again issue an instruction to the first master clock 134 not to issue the signal CLK-A to all of the clock-demanding components of the multi-chassis broadcast router 100. Initially, the first state machine is in the first state 158. In this state, the input from the routing engine 140 indicates that first router matrix card 102a is present and running and the input from the transmission expansion port 146 indicates that it is locked. The inputs from the routing engine 150 and the transmission expansion port 152 are irrelevant. In the first state 158, the first state machine 148 issues a signal to the first master clock 158 instructing the first master clock 158 to provide the common clock signal CLK-A to all of the clock-demanding components of the multi-chassis broadcast router 100. Furthermore, as all of the clock-demanding components of the multi-chassis broadcast router 100 are receiving the common clock signal CLK-A from the first master clock 134, the status of the broadcast router is "FULL", i.e., all of the broadcast router components 102, 104, 106 and 108 are operating.

Regardless of operating conditions for the second master clock 154, the first master clock 134 will continue to supply the common clock signal CLK-A until either the routing engine 140 or the transmission expansion port 146 fail. A routing engine failure occurs if the input from the routing engine 140 changes such that it now indicates that the first router matrix card 102a is either absent or no longer running. A transmission expansion port failure occurs if the input from the transmission expansion port 146 indicates that the clock signal is no longer constant. If either of these conditions occurs, the first state machine 140 will transition to the third state 162. In this state, the first state machine 148 issues a signal to the first master clock 134 not to distribute the common clock signal CLK-A to the clock-demanding components of the multi-chassis broadcast router 100. As may be seen in Table I, whether or not all, part or none of the clock-demanding components of the broadcast router 100 will have a common clock signal will depend on the state of the second state machine 156.

From the third state 162, the first state machine 148 will transition to either the first state 158 or the second state 160. This transition will occur when the input from the routing engine 140 again indicates that the first router matrix card 102a is present and running and the input from the transmission expansion port 146 again indicates that the port is locked. The particular transition that will occur depends on the condition of the second state machine 156. More specifically, if the second state machine 156 is in a first ("master") state 164, the second state machine 156 is currently issuing a signal to the second master clock 154 to distribute the common clock signal CLK-B to the clock-demanding components of the broadcast router 100. If the second master clock 154 is distributing the common clock signal CLK-B, the third and fourth inputs to the first state machine 148 will indicate that the redundant router matrix card 104b is okay and the transmission expansion port 152 is locked. In response, the first state machine 148 will transition to the third state 160 where it will issue an instruction to the first master clock 134 to not distribute the common clock signal CLK-A. If, however, the second state machine 156 is in any other state, the first state machine 148 will transition to the first state 158 where it will again issue a signal to the first master clock 134 to distribute the common clock signal CLK-A.

From the second state 160, the first state machine 148 will transition to either the third state 162 or the first state 158. The transition to the third state 162 can occur independent of the second state machine 156. Specifically, the first state machine 148 will transition to the

third state 162 if the first input thereto indicates that the routing engine 140 has failed or if the second input thereto indicates that the transmission expansion port 146 has failed. The transition to the first state 158, on the other hand, can only occur as a result of the second state machine 156 undergoing a transition. Specifically, if the second state machine 156 transitions from the first state 164 to a third state 168, the third or fourth inputs to the first state machine 148 will indicate that the redundant router matrix card 104b is not okay and/or the transmission expansion port 146 is not locked.

Referring next to FIG. 5, the state machine has four states, the first state 164 in which the second state machine 156 issues an instruction to the second master clock 154 to issue the signal CLK-B to all of the clock-demanding components of the multi-chassis broadcast router 100, a second state 166 where the second state machine 156 issues an instruction to the second master clock 154 not to issue the signal CLK-B to all of the clock-demanding components of the multi-chassis broadcast router 100, the third state 168 where the second state machine 156 will again issue an instruction to the second master clock 154 not to issue the signal CLK-B to all of the clock-demanding components of the multi-chassis broadcast router 100 and a fourth ("wait" (or "W")) state 160 in which the second state machine 156 again issues an instruction to the second master clock 154 not to issue the signal CLK-B to all of the clock-demanding components of the multi-chassis broadcast router 100. Initially, the second state machine 156 is in the second state 158. In this state, the input from the routing engine 140 indicates that primary router matrix card 102a is present and running and the input from the transmission expansion port 146 indicates that it is locked. Similarly, the inputs from the routing engine 150 indicates that the redundant router matrix card 104b is present and running and the input from the transmission port 152 indicates that it is locked. In the second state 166, the second state machine 156 issues a signal to the second master clock 154 instructing the second master clock 154 not to provide the common clock signal CLK-B to all of the clock-demanding components of the multi-chassis broadcast router 100.

From the second state 166, the second state machine may transition to either the third state 168 or the first state 164. Transition to the third state 168 may occur regardless of the state of the first state machine 148. More specifically, the state machine 156 will transition to the third state 168 if the input from the routing engine 150 indicates that the redundant router matrix card 150 has failed or the input from the transmission expansion port 156 indicates it is no longer locked. In the third state 168, the state machine 156 will again issue an instruction

to the second master clock 154 instructing the master clock 154 not to distribute the common clock signal CLK-B to the clock-demanding components of the multi-chassis broadcast router 100. Conversely, the second state machine 166 can only transition from the second state 166 to the first state 164 upon transition of the first state machine 148 from either the first state 158 or the second state 160 into the third state 162. The second state machine 156 will be  
5 advised that such a transition has occurred upon the input from the routing engine 140 indicating that the primary router matrix card 102a has failed or the input from the transmission expansion port 146 indicating that the clock signal is no longer constant. If either of these conditions occurs, the second state machine 156 will transition from the second  
10 state 166 to the first state 164. In this state, the second state machine 156 issues a signal to the second master clock 154 to distribute the common clock signal CLK-B to the clock-demanding components of the multi-chassis broadcast router 100.

From the first state 164, the second state machine 156 may only transition to the third state 168. This transition can only occur upon transition of the first state machine 148 from  
15 either the first state 158 or the second state 160 into the third state 162. The second state machine 156 will be advised that such a transition has occurred upon the input from the routing engine 140 indicating that the primary router matrix card 102a has failed or the input from the transmission expansion port 146 indicating that the clock signal is no longer constant. If either of these conditions occurs, the second state machine 156 will transition  
20 from the first state 164 to the third state 168. In this state, the second state machine 156 issues a signal to the second master clock 154 to not distribute the common clock signal CLK-B to the clock-demanding components of the multi-chassis broadcast router 100.

From the third state 168, the second state machine 156 may only transition to the fourth state 160. This transition can only occur upon the input from the routing engine 150  
25 indicating that the redundant router matrix card 104b is present and running and/or the input from the transmission expansion port 152 indicating that the port is locked. In the fourth state 170, the second state machine 156 will issue a signal to the second master clock 154 not to distribute the common clock signal CLK-B to the clock-demanding components of the broadcast router 100. Finally, from the fourth state 170, the second state machine 156 may  
30 transition to any one of the first, second or third states 164, 166 or 168. More specifically, the second state machine 156 will transition to the first state 164 if the input from the routing engine 140 indicates that the primary router matrix card has failed and/or the input from the

transmission expansion port 146 indicates that the port is not locked. Conversely, the second state machine 170 will transition to the second state 166 if the input from the routing engine 140 indicates that the primary router matrix card 102a is present and running and the input from the transmission expansion port 146 indicates that the port is locked. Finally, the second  
5 state machine 170 will transition to the third state 168 if the input from the routing engine 150 indicates that the redundant router matrix card 104b has failed and/or the input from the transmission expansion port 152 indicates that the port is not locked.

Of course, while preferred embodiments of this invention have been shown and described herein, various modifications and other changes can be made by one skilled in the art  
10 to which the invention pertains without departing from the spirit or teaching of this invention. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow.